THE EXPLORATION OF PHOBOS AND THE CONSTANT OF GRAVITATION

A. Finzi*

Institute for Space Studies
Goddard Space Flight Center, NASA
New York, New York

GPO PRICE $ ________

CSFTI PRICE(S) $ ________

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

N68-19139

(ACCESSION NUMBER)	(THRU)
10 (PAGES)	1 (CODE)
TMX-60921 (NASA CR OR TMX OR AD NUMBER)	30 (CATEGORY)

FACILITY FORM 602

*On leave from the Laboratorio di Astrofisica, Frascati, Italy.

ABSTRACT

It would be easier to land a spacecraft gently on Phobos, the tiny Martian moon, than on Mars. The study of Phobos' material could provide information about the origin of Mars. Detailed information about the Martian relief could be derived from the analysis of the radio signals before and after each occultation of Phobos by Mars. Finally, the Doppler Tracking Data would yield the accurate values of the coefficients of the development of Mars' potential in spherical harmonics and would provide an opportunity to test the hypothesis that Newton's constant varies with the gravitational potential. The result of this test could have fundamental implications in Relativistic Astrophysics and Cosmology.

It is generally held that, after the Moon has been explored, Venus and Mars should be the objectives of the next soft landings. Information about these two planets gathered in the last few years indicates, however, that the task would be more difficult than was assumed in the past. The surface of Venus is so hot that after the landing the instruments carried by a spacecraft may not continue to work for the time needed for the acquisition of significant information; Mars's atmosphere is so thin that it may be of only limited help in the execution of a soft landing. It is the purpose of this letter to suggest that a landing on Phobos, one of the two tiny Martian moons, would be technically easier and scientifically more rewarding.

The radius of the orbit of Phobos is 3 times larger than the radius of Mars; therefore, the binding energy in the gravitational field of Mars would be about 6 times smaller for a spacecraft orbiting with Phobos than for a spacecraft on the same mass standing on the surface of Mars. This means that considerably less fuel would be needed for a mission to Phobos than for a mission to Mars.

As the gravitational pull of Phobos is weak, the task of bringing a spacecraft to rest in a frame of reference moving with Phobos could be performed leisurely, and would not involve technical problems similar to those connected with a landing on either the Moon or Mars. The escape velocity from Phobos is, however, not completely negligible (of the order of 10m/sec) and a hopping spacecraft could easily reach, by successive attempts, the position suitable for any particular experiment.

Finally, the period of rotation of Phobos is probably equal to the period of revolution, which is less than 8 hours. Therefore, a spacecraft on its surface would not have to face the rather extreme temperatures that often shorten the useful life of instruments on the Moon.

Let us now consider what results could presumably be achieved by a soft landing on Phobos.

1. It seems a safe assumption that Phobos and Mars have a common origin. Since Phobos is small, its material probably did not go through conditions of high temperatures or high density after the separation from Mars, and has thus retained its original

characteristics. The study of this material could thus yield information about the origin of the planet.

It could be of some interest to compare the density of material of Phobos to the average density of Mars.

2. Usually, Phobos is occulted by Mars in the course of its revolution. Only when the intersection between the orbital plane of Phobos and the plane of the ecliptic makes an angle close to 90° with the line of sight, does the occultation not occur. The analysis of the radio signal from the spacecraft before and after each occultation could yield the atmospheric density at the diffracting edges[1], and thus the relative altitudes of the edges. Detailed information about the Martian relief could thus be obtained.

3. The Doppler tracking data of the radio signal from the spacecraft could yield the radial component of its velocity with an error smaller that 0.1 cm/sec.;[1,2] the trajectories of Mariner IV and Mariner V have been accurately determined in this way. The

trajectory of Phobos could be determined with an even better accuracy since it is not affected appreciably by rather unpredictable perturbations like radiation pressure and electrostatic forces which are important for artificial satellites. It would thus be possible to determine the first coefficients of the development of Mars's potential in spherical harmonics with an accuracy better than that achieved so far in the determination of the coefficients of the Earth's potential.

4. The observations considered so far would be relevant for the study of Mars; we shall now mention briefly an experiment which could have implications in Relativistic Astrophysics and Cosmology. A fuller description of this proposed experiment will appear elsewhere.

It has often been suggested that the value of Newton's constant G may be affected by the presence of large masses in the neighborhood of the two bodies used in the measurement; in the frame of Mach's ideas this is a rather natural suggestion. In the non-relativistic limit the influence of the large masses can appear only through the gravitational potential V; a dimensional argument then leads to the relation[3-10]

$$G = G_o \left(1 + a \frac{V}{c^2} \right) \tag{1}$$

where a is a constant of the order of unity. This simple law can be supposed to hold only in the case in which one can neglect the variation of V throughout the ragion where the two bodies are placed and the contribution of the two bodies to V.

Let now

$$r = \frac{r_o}{1 + e \cos \theta}$$

be the equation of the orbit of Mars; since the eccentricity e has the rather large value 0.093313, the solar gravitational potential at the position of Mars varies considerably during the Martian year. Thus equation (1) can be tested and a can be determined by observing the motion of Phobos under the gravitational attraction of Mars.

The effect of the variation of G on the orbit of Phobos would be negligible, but the change in the temporal law of motion would be detectable. Let the position of Phobos be determined initially when the true anomaly θ of Mars is an odd multiple of $\frac{\pi}{2}$. The variation of G will result in an advanced or delay of 19.4 a msec in the motion of Phobos at the time that θ has increased by π. However, Phobos will again run on schedule at the time that θ has further increased by π and Mars has completed one revolution.

For simplicity, we shall discuss here the detectability of this effect neglecting the existence of all other perturbations acting on Phobos. The acceleration of Phobos in the gravitational field of Mars is about 57 cm sec^{-2}. Therefore, when Phobos and Mars are close to conjunction and the acceleration of Phobos is in the direction of the line of sight, an advance or delay of 19.4 $\underline{a}$ msec will result in a difference of 1.1 $\underline{a}$ cm sec^{-1} in the radial velocity. As mentioned above, the Doppler tracking data could yield the velocity of the spacecraft with an error smaller than 0.1 cm sec^{-1}; the formal error in the determination of $\underline{a}$ would thus be less than 0.09.

A more complete discussion would show that the small perturbation caused by the variation of G could indeed be separated from other larger perturbations acting on Phobos; the two basic points in the discussion would be that the number of important perturbative terms is quite limited, and that perturbations that cannot be calculated accurately, like radiation pressure and electrostatic forces, can be neglected owing to the relatively large mass of Phobos.

To conclude, it should be mentioned that Phobos appears merely as a point-like object to a terrestrial observer; its size and its mass are estimated by assuming that its albedo and its density have values similar to those of other satellites. More could be learned about Phobos if the plans for the coming fly-by mission to Mars would include a photographic study of this satellite.

ACKNOWLEDGMENT

I am indebted to H. Chiu, J. Cohen, G. Colombo, R. O'Connell W. Priester and R. A. Wolf for helpful suggestions. Ruth Finzi advised me in the preparation of the manuscript.

It is a pleasure to thank Dr. Robert Jastrow for the hospitality at the Institute for Space Studies. This work was done while I held a NAS-NRC Research Associateship at the Institute for Space Studies, Goddard Space Flight Center, NASA, New York.

1. Kliore, A., Cain, D. L., Levy, G. S., Eshleman, V. R., Fjeldbo, G. and Drake, F. D., Science 149, 1243 (1965).
2. Anderson, J. D., Pease, G. E., Efron, L., and Tausworthe, R.G. paper presented at the 125th Meeting of the American Astron. Soc. (1967).
3. Sciama, D. W., Monthly Notices Roy. Astron. Soc. 113, 34 (1953).
4. Dicke, R. H., Revs. Modern Phys. 29, 363 (1957).
5. Jordan, P., Z. Physik 157, 112 (1959).
6. Brans, C., and Dicke, R. H. Phys. Rev. 124, 925 (1961).
7. Brans, C., Phys. Rev. 125 2194 (1962).
8. Dicke, R. H., Phys. Rev. 125 2163(1962).
9. Finzi, A., Phys. Rev. 128, 2012 (1962).
10. Finzi, A. Annals of Physics 26 411 (1964).